

# NASA TECH BRIEF

## Marshall Space Flight Center



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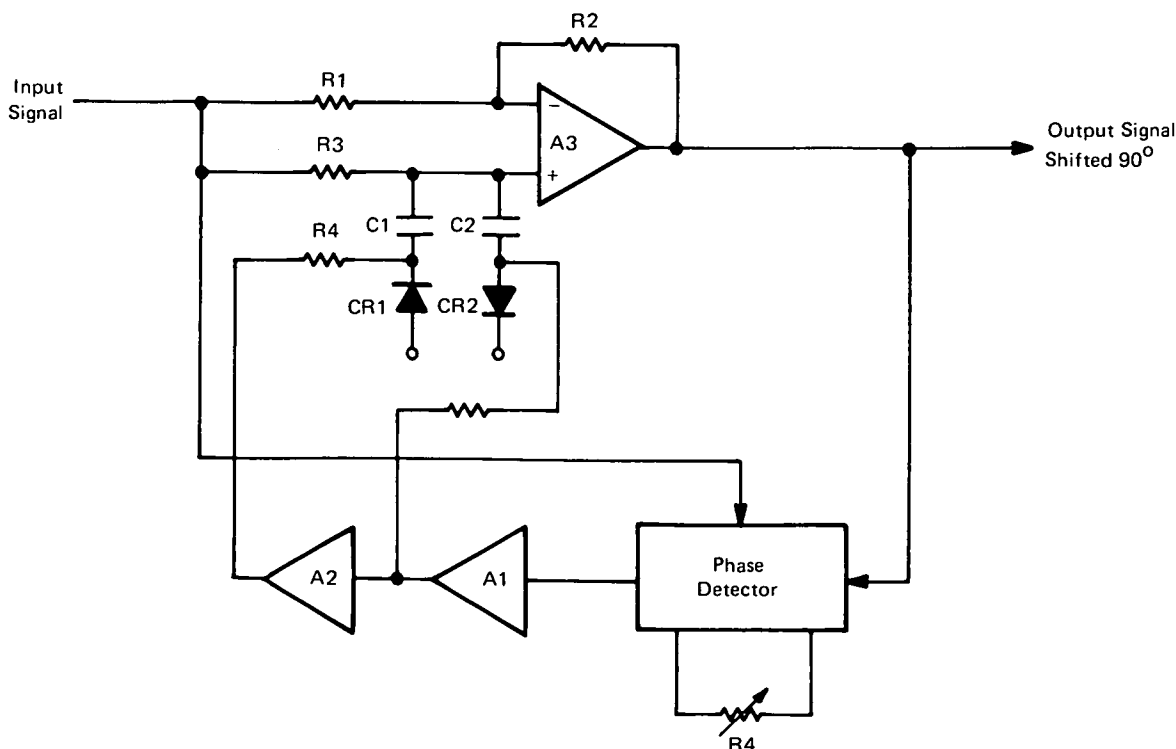
### Low Distortion Automatic Phase Control Circuit

In the generation and demodulation of quadrature double side band signals in a frequency division multiplexing system, a  $90^\circ$  phase shifter is required. The  $90^\circ$  phase shift must be independent of frequency over small frequency changes and must also be capable of handling large amplitude sine wave signals without distortion. In this automatic phase control circuit (see figure) the phase shifter uses an operational amplifier with external resistors and capacitors which control the gain and phase shift of the output voltage relative to the input voltage. The operational amplifier, in conjunction with  $R_1$  and  $R_2$  forms an inverting amplifier with a gain approximately equal to the ratio of  $R_2/R_1$  and a 180 degree

phase shift. An additional phase shift of 90 degrees results from the use of the second (positive input) of the two differential inputs of the operation amplifier. Signal applied to the positive input through a resistor-capacitor network increases the overall phase shift by an additional 90 degrees. For  $R_2=R_1$  the phase lag,  $\theta_{lag}$  may be found from the expression:

$$\theta_{lag} = (180 - 2 \tan^{-1} \omega C_t R_3)$$

Where  $C_t$  is the series-parallel combination of  $C_1$ ,  $C_2$ ,  $CR_1$  and  $CR_2$  and  $\omega = 2\pi f$  where  $f$  is the modulated carrier frequency. Varactors  $CR_1$  and  $CR_2$  are biased



Automatic Phase Control Circuit

(continued overleaf)

in opposite directions and driven from inverted voltages provided by amplifier  $A_2$  such that the reverse bias on each varactor is equal to the other for any given control voltage.

The capacitance across the varactor diode junction depends on the reverse bias voltage. The two varactors are operated on the same portion of their capacitance versus voltage curve. For matched curves, the capacitance, and therefore phase lag, is independent of the input voltage swing. As a result, there is no distortion of the input signal either in phase or in amplitude such as would occur when a nonlinear element such as only one varactor or FET is used.

It can be seen from the phase lag equation that  $\theta$  is a function of frequency as well as capacitance. Therefore, to provide a constant phase over a small frequency range, a closed loop phase control system is required. The control loop consists of a phase detector and associated amplifiers. The input and output voltages of the phase shifter are compared in the phase detector with the resulting error voltage amplified by  $A_1$  and  $A_2$  to control the bias applied to the varactors. This automatically compensates for any phase variation caused by variations in input frequency or component changes. The output phase can be held to 0.1% of any given phase lag between  $180^\circ$  and  $360^\circ$  with frequency changes of up to 10%.  $R_4$  in the phase detector allows for a

small amount of phase adjustment for phase alignment of the system. This circuit has been operated with an input and output voltage of 6V p-p with harmonic distortion down 70 dB or better.

#### Notes:

No additional information exists on this innovation. Specific questions, however, may be directed to:

Technology Utilization Officer  
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#### Patent status:

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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